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Space Administration

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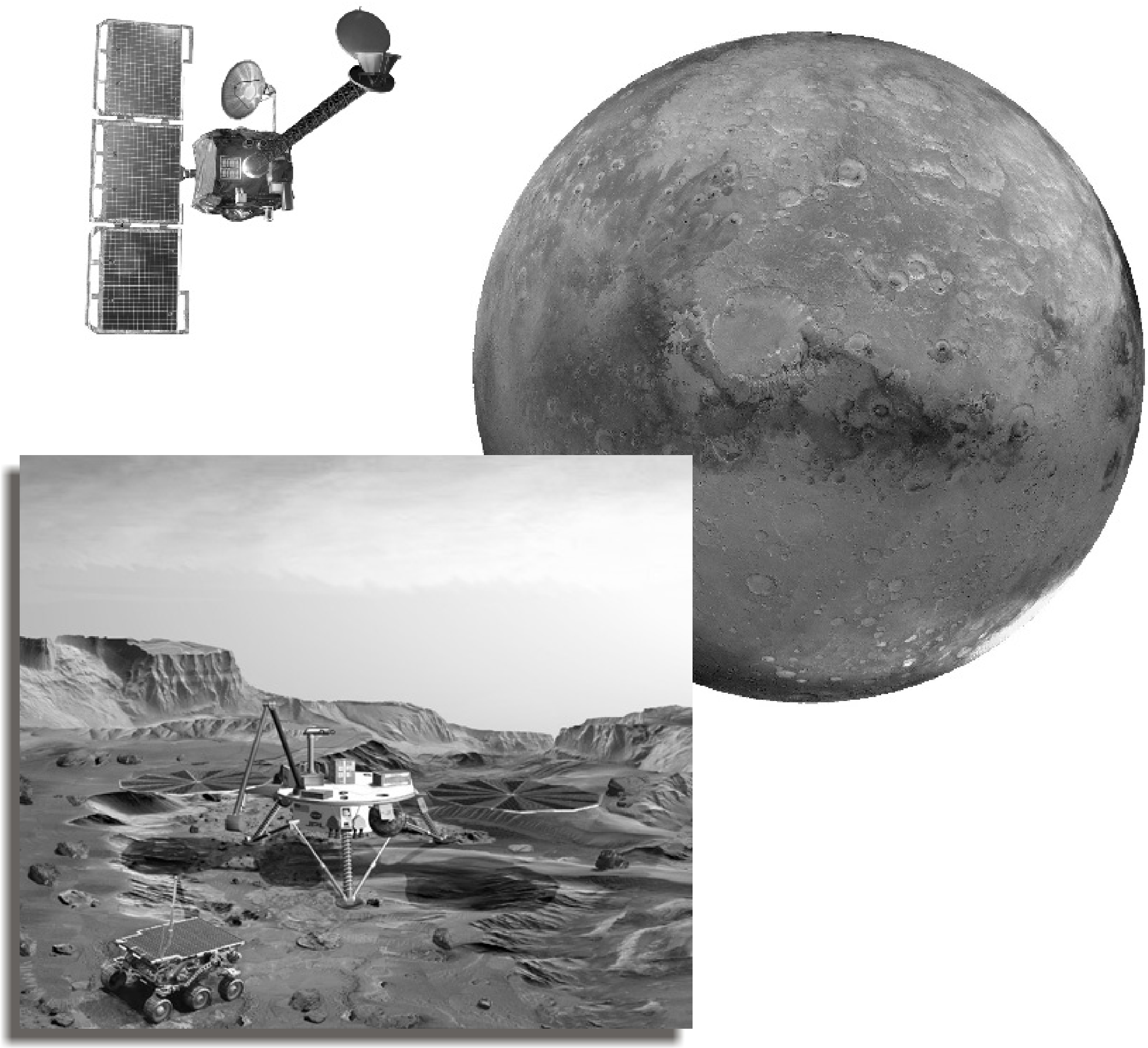
Draft Environmental Impact Statement for the Mars Surveyor 2001 Mission



DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE MARS SURVEYOR 2001 MISSION

Office of Space Science
National Aeronautics and Space Administration
Washington, DC 20546

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ABSTRACT

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DATE:	November 1999

This Draft Environmental Impact Statement addresses the potential environmental impacts associated with continuing the preparations for and implementing the Mars Surveyor 2001 mission. As proposed, this mission would continue the long-term exploration of Mars as part of the United States' Mars Surveyor Program.

The Proposed Action for the Mars Surveyor 2001 mission (MS 01) would consist of two launches: an orbiter spacecraft launched from Vandenberg Air Force Base, California, on a Delta II 7925 launch vehicle in March/April 2001, and a lander/rover spacecraft launched from Cape Canaveral Air Station, Florida, on a Delta II 7425 launch vehicle in April 2001. These launch opportunities would place the two spacecraft (orbiter and lander/rover) into separate direct trajectories to Mars.

Alternatives to the Proposed Action that were evaluated consist of:

- Orbiter and Lander-Only Mission Alternative – this alternative would be implemented in the same manner as the Proposed Action with the exception that the rover would be eliminated from the lander/rover spacecraft and only the orbiter and lander would be separately launched.
- Orbiter-Only Mission Alternative – this alternative would be implemented in the same manner as the Proposed Action except that only the orbiter would be launched; the lander/rover spacecraft and its launch would be eliminated.
- No-Action Alternative – NASA would cease preparations for the MS 01 mission; neither spacecraft would be launched.

The potential environmental impacts of implementing the Proposed Action and alternatives were evaluated. With the exception of the No-Action Alternative, the environmental impacts of preparations for and launch of the MS 01 spacecraft under the Proposed Action, the Orbiter and Lander-Only Mission Alternative, and the Orbiter-Only Mission Alternative were determined to be confined largely to the launches themselves. The environmental impacts associated with the normal launch of the MS 01 spacecraft would be the same as other Delta II launches from CCAS and VAFB and have been addressed in prior NASA and U.S. Air Force environmental documentation. These impacts have been determined to be primarily associated with the exhaust products resulting from the launch vehicle's solid rocket motors and main engines. Expected environmental effects would include short-term impacts to air quality at and near the launch pads, short-term impacts to stratospheric ozone, and in the case of the orbiter launch from VAFB, disturbance of some Federally protected species, and possibly even some mortality, of a protected bird species that nests near the launch site. These potential impacts at VAFB were addressed by the U.S. Air Force with the U.S. Fish and Wildlife Service in a Biological and Conference Opinion completed in early 1999. An incidental take permit and mitigation plans are in place. A similar concern does not exist at CCAS. There would be no environmental impacts associated with the No-Action Alternative.

Another concern is the potential for launch accidents that may result in release of some of the radioactive material on board the MS 01 lander and the rover. The lander would employ two minor radioactive sources on science instrumentation, and, in the case of the Proposed Action, the rover would be equipped with two minor radioactive instrument sources and three radioisotope heater units (RHUs) as a source of heat for onboard electronics and batteries. This concern applies to the Proposed Action and to the Orbiter and Lander-Only Mission Alternative. There is no radioactive material on board the orbiter for the Orbiter-Only Mission Alternative, and under the No-Action Alternative there would be no launches.

The U.S. Department of Energy, as NASA's cooperating agency, prepared a detailed risk assessment of potential launch accidents and radiological consequences to human health and the environment, as well as estimates of the risks associated with each phase of the mission. DOE's risk assessment indicated that the potential radiological consequences associated with mission accidents were low, and the radiological risks associated with the overall mission were also low.

Implementation of the Proposed Action would accomplish all of the scientific goals and objectives set out for the MS 01 mission, and a substantial contribution would be made to efforts to explore and understand Mars. The Orbiter and Lander-Only Mission Alternative would accomplish all but the science objectives associated with the rover (principally investigations of mineralogic composition of the surface and educational opportunities). The Orbiter-Only Mission Alternative would accomplish about 10 percent of the overall scientific goals and objectives of the Proposed Action MS 01 mission. The No-Action Alternative would result in loss of the 2001 mission opportunity and would impact attainment of NASA's long-term science objectives for the exploration of Mars.

EXECUTIVE SUMMARY

This Draft Environmental Impact Statement (DEIS) for the Mars Surveyor 2001 Mission has been prepared in accordance with the National Environmental Policy Act of 1969, as amended (NEPA) (42 U.S.C. 4321 et seq.); Executive Order 12114, “Environmental Effects Abroad of Major Federal Actions;” the Council on Environmental Quality Regulations for Implementing the Procedural Provisions of NEPA (40 CFR Parts 1500-1508); and the National Aeronautics and Space Administration's (NASA's) policy and procedures (14 CFR Subparts 1216.1 and 1216.3). The purpose of this DEIS is to assist in the decisionmaking process concerning the Proposed Action and alternatives for the Mars Surveyor 2001 (MS 01) mission of the Mars Surveyor Program.

The Mars Surveyor Program consists of a series of missions, launched during every opportunity to Mars (approximately every 26 months), that are directed at attaining the Nation’s broader goals of Mars exploration. NASA's original intent was to prepare a tiered programmatic EIS that would encompass, in one or more NEPA documents, a series of three missions, beginning with MS 01, which were proposed to eventually culminate in the return to Earth by 2008 of samples collected on the surface of Mars. In addition, it was intended that the first tiered programmatic EIS would encompass mission-specific details for both the MS 01 mission and the mission planned for the following opportunity, Mars Surveyor 2003. At that time, it was planned that both missions would use identical lander/rover spacecraft to achieve their common scientific objectives, which included collecting and storing samples of Mars for possible retrieval and return to Earth by a later mission. For a variety of technical and programmatic reasons, NASA reduced the scope of the MS 01 mission such that sample collection for return to Earth is no longer among its objectives. Therefore, this DEIS addresses only the specific environmental impacts associated with the MS 01 mission. Later missions in the Mars Surveyor Program, including Mars sample return missions, will be covered by subsequent environmental documentation.

PURPOSE AND NEED FOR ACTION

For many years, Mars has been a primary focus for scientists due to its potential for past biological activity and for comparative studies with Earth. NASA has established the Mars Surveyor Program as a series of missions to characterize the planet and its atmosphere, its geologic history, its climate and the relationship to Earth's climate change process; to determine what resources it provides for future exploration; and to search for evidence of past or present life. The scientific objectives of the program include the completion of the global reconnaissance of the planet, in situ exploration of diverse areas of the surface, and return of samples of the Martian surface for intensive analysis in Earth-based laboratories. The MS 01 mission would support these science objectives by continuing the global reconnaissance of Mars, via an orbiter spacecraft, and continuing the intense study of local areas of the surface, via a lander/rover spacecraft.

ALTERNATIVES EVALUATED

The Proposed Action consists of continuing preparations for and implementing the MS 01 mission. The MS 01 orbiter would be launched on a Delta II 7925 from

Vandenberg Air Force Base (VAFB), California in March/April 2001. The MS 01 lander carrying the rover would be launched on a Delta II 7425 from Cape Canaveral Air Station (CCAS), Florida in April 2001. Alternatives to the Proposed Action that were evaluated consist of:

- ♦ Orbiter and Lander-Only Mission Alternative: Launch the MS 01 orbiter as planned in the Proposed Action; eliminate the rover, and launch the lander-only spacecraft as planned in the Proposed Action; perform remote science data gathering from orbit and stationary in situ science by the lander.
- ♦ Orbiter-Only Mission Alternative: Launch the MS 01 orbiter as planned in the Proposed Action; eliminate the lander/rover launch; perform only remote science data gathering from orbit.
- ♦ No-Action Alternative: NASA would cease preparations for, and not implement the MS 01 mission.

The following discusses the potential environmental impacts associated with implementation of the Proposed Action and the alternatives. Because the Proposed Action and the Orbiter and Lander-Only Mission Alternative would each employ radioactive material that could potentially be released in the event of a launch vehicle accident, a separate discussion is provided for the Proposed Action and this alternative. The radiological impact discussion is then followed by a brief evaluation in terms of the amount of mission science that could be obtained and the implication to NASA's longer-term efforts to characterize Mars and answer fundamental questions regarding the planet.

ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION AND ALTERNATIVES

Nonradiological Consequences of the Proposed Action and Alternatives

For the MS 01 mission, the potentially affected environment includes the areas on or near the vicinity of the two launch sites, CCAS in Florida and VAFB in California. The potential environmental consequences of Delta II launch vehicles have been addressed in prior U.S. Air Force and NASA NEPA documents (USAF 1997; USAF 1998; NASA 1998a; NASA 1998b). All activities at CCAS and VAFB associated with the MS 01 mission would be accomplished under existing environmental licenses and permits.

The environmental impacts of normal launches of the two spacecraft for the Proposed Action would be associated principally with the exhaust emissions from each of the Delta II launch vehicles. These effects would include short-term impacts on air quality within the exhaust cloud at and near the launch pads, and the potential for acidic deposition on the vegetation and surface water bodies at and near each launch complex, particularly if a rain storm occurred. The potential exists for disturbance of some protected species near the VAFB launch site, and possible mortality of a few individual protected birds. This has been addressed by the U.S. Air Force with the U.S. Fish and Wildlife Service in a Biological and Conference Opinion completed in early 1999, and an incidental take permit and mitigation plans are in place. A similar concern does not exist at CCAS. Some short-term ozone degradation would occur along the flight paths as each launch vehicle passes through the stratosphere and deposits ozone-depleting chemicals from the solid rocket motors.

Implementation of the Orbiter and Lander-Only Mission Alternative would involve the same environmental impacts as described for the Proposed Action. The Orbiter-Only Mission Alternative would involve only the one launch from VAFB described for the Proposed Action. The environmental impacts associated with the launch of the Delta II launch vehicle would be the same as those under the Proposed Action. There would be no environmental impacts associated with the No-Action Alternative.

Radiological Consequences of Potential Launch Accidents for the Proposed Action and Alternatives

A concern associated with launch of the MS 01 lander/rover spacecraft involves potential launch accidents that could result in release of some of the radioactive material onboard the lander/rover spacecraft. The lander would employ two instruments which use small quantities of cobalt–57 (about 1.30×10^{10} becquerels or 350 millicuries) and about 7.40×10^{5} becquerels (20 microcuries) of curium–242 as instrument sources. The rover would have three radioisotope heater units (RHUs) which use plutonium dioxide to provide heat to the electronics and batteries on board the rover. The radiological inventory of the three RHUs would total 3.69×10^{12} becquerels (99.6 curies). The rover would also carry a small amount of curium–244 (3.70×10^{9} becquerels (100 millicuries)) on its spectrometer and a small americium–241 source (1.11×10^{6} becquerels (30 microcuries)) on a dust experiment package.

NASA's cooperating agency, the U.S. Department of Energy (U.S. DOE), has performed a risk assessment of potential accidents for the MS 01 lander/rover. This assessment uses a methodology refined through applications to the Galileo, Cassini, and Mars Pathfinder missions, and incorporates safety tests on the RHUs as well as evaluation of the January 17, 1997, Delta II accident at CCAS. The U.S. DOE's risk assessment for this mission indicates that the expected impacts of released radioactive material on or near the launch area, and on a global basis, would be small.

Methodology

In its *Nuclear Risk Assessment for the Mars 2001 Mission Draft Environmental Impact Statement* (USDOE 1999), the U.S. DOE divided launch of the MS 01 lander/rover spacecraft from CCAS into four principal phases corresponding to mission elapsed time segments. The mission phases extend from about 2 days prior to launch during which fueling operations take place at the launch pad, through injection of the MS 01 lander/rover spacecraft into its direct trajectory to Mars at about 2008 seconds after launch. Each phase corresponds to major launch activities and launch vehicle events with the time periods during which the CCAS launch area, its surrounding region, and other areas of the Earth may be impacted by an accident that releases radioactive material. The mission elapsed-time phases utilized in the U.S. DOE risk assessment are as follows.

Phase 0 (Pre-Launch) – This phase extends from about 2 days prior to launch up to the time of ignition of the Delta II solid rocket graphite epoxy motors (GEMs) and first stage liquid fueled main engine; the mission elapsed time segment for Phase 0 is expressed as T (time) < (less than) 0 seconds.

Phase 1 (Launch)—This mission elapsed-time phase extends from ignition of the Delta II engines at T=0 to 270 seconds later when the Delta II first stage has been separated from the launch vehicle (the GEMs separate at about 66 to 67 seconds); during this phase the Delta II launch vehicle lifts off the pad, accelerates, and gains altitude, proceeding down range over the Atlantic Ocean. The U.S. DOE further divided Phase 1 into discrete mission elapsed-time segments for the purposes of its risk assessment. As the launch proceeds through Phase 1, the accident types and environments change. Phase 1 was divided as follows:

— Launch time segment extends from T=0 seconds to T=5 seconds, during which the launch vehicle is lifting off the pad and clearing the launch tower;

— Early Launch time segment extends from T=5 seconds to T=38 seconds, during which the launch vehicle clears the tower, gains altitude, and starts to clear land; and

— Late Launch time segment extends from T=38 seconds to T=270 seconds, during which the GEMs and the main engine first stage completes their burns, are jettisoned, and the vehicle is well out over the Atlantic Ocean; after T=38 seconds, launch vehicle accidents would no longer impact land in the CCAS region.

Phase 2 (Pre-Orbit/Orbit)—This phase extends from just after T=270 seconds to T=1596 seconds during which the Delta II second stage completes its burns and is jettisoned, the STAR 48B upper stage and the MS 01 lander/rover spacecraft enter Earth parking orbit in preparation for Phase 3.

Phase 3 (Earth Escape)—This phase extends from just after T=1596 seconds to about T=2008 seconds when the Mars 01 lander/rover spacecraft would be successfully injected into its direct trajectory to Mars by the solid propellant STAR 48B upper stage.

The U.S. DOE’s methodology utilizes three major steps: (1) evaluation of potential accident scenarios within each phase to determine whether or not a release of radioactive material would be likely to occur, and if so, the potential amount of material released and the associated probability; (2) estimation of the potential radiological consequences that could be associated with each accident scenario release using transport and dispersion models that incorporate appropriate meteorological parameters and internationally recognized radiological exposure pathway parameters; and (3) estimation of potential risks to human health associated with the radiological consequences.

The radiological consequences of a given accident scenario resulting in a release of radioactive material were estimated in terms of (1) maximum individual dose; (2) collective dose to a potentially exposed population; (3) the number of potential health effects that could result from the collective dose; and (4) the area of land at or near CCAS potentially contaminated at or above a representative level.

The maximum individual dose is an estimate of the largest dose from radioactive material a single individual would potentially receive as a result of a given accident scenario. Collective or population dose is an estimate of the total dose received by the population that could potentially be exposed to a radioactive material release from each accident scenario. Health effects are an estimate of the number of excess cancer fatalities that would be expected to occur as a result of an accident which released radioactive material, over and above the number of cancer fatalities that would normally be observed in the exposed population.

Having developed estimates of the radiological consequences, the U.S. DOE then developed estimates of risk. Risk is defined as the total probability of an event occurring (in this case, an accident resulting in release of radioactive material) multiplied by the consequences of that event (in this case, the number of health effects). The U.S. DOE estimated the risk for each phase and for the overall mission.

Radiological Consequences

While accidents potentially resulting in a release of radioactive material could occur in the later mission phases (Phase 2 and Phase 3), near-pad accidents of Phase 1 are the principal contributors to overall mission risks, accounting for about 74 percent of that risk. Therefore, this discussion focuses on the radiological consequences of potential accidents for both Phase 1 and the overall mission. The radiological consequences are provided for the expectation (mean) case, which represents the consequences and risks that would be anticipated should a mission accident occur. Under the Proposed Action, the total probability of a Phase 1 accident resulting in a release of radioactive material was estimated to be 3.15×10^{-3}, or 1 chance in 317, while for the overall mission the total probability of an accident release is 1.07×10^{-2}, or 1 chance in 93. The primary contributor to Phase 1 accident consequences is an accident leading to an intact impact on land of the STAR 48B upper stage with the spacecraft attached. Assuming an accident did occur during Phase 1, the amount of radioactive material expected to be released (source term) would be small, representing a very small fraction of the total inventory on board the Proposed Action’s lander/rover, about 0.21 percent in a Phase 1 accident, and about 0.22 percent across the overall mission. The Phase 1 source term would consist of about 60 percent from the minor sources (principally cobalt–57 and curium–244) with the remainder from the RHUs; the source term for the overall mission would be similar at about 62 percent from the minor sources.

A Proposed Action Phase 1 accident resulting in a release would be expected to result in a total collective (population) dose of about 35.6 person-rem over a 50-year period (for the mission as a whole, across all mission accidents and mission phases, the expectation (mean) collective dose was estimated as 14 person-rem over a 50-year period). (Collective dose is the sum of all the doses received by all of the individuals within the exposed population - on the order of 100,000 for the Phase 1 analysis. As a frame of reference, a population of 100,000 in the U.S. would be expected to receive a collective dose of natural background radiation of about 30,000 person-rem over a 1-year period.) Using radiological exposure pathway parameters and models developed by recognized authorities, consisting of the National Council on Radiation Protection and Measurements (NCRP) and the International Commission on Radiological Protection (ICRP), the expected number of health effects (excess cancer fatalities over 50 years) in the exposed population was estimated.

Applying these exposure pathway parameters and models, the expected (mean) number of excess cancer fatalities within the exposed population for a Proposed Action

Phase 1 accident would be about 0.0175, and about 0.00692 for all mission accidents. For the Proposed Action, the probability of one or more excess cancer fatalities for both Phase 1 and for the overall mission accident would be about 1 in 330,000. The risk associated with a Phase 1 accident was estimated to be 5.50×10^{-5}, and 7.40×10^{-5} for the overall mission.

Based on uncertainty analyses performed for previous missions, the uncertainties associated with evaluation of accident probabilities, source terms, and radiological impacts could lead to risk estimates that vary by 1 to 2 orders of magnitude (10 to 100 times greater or less than those estimated in the analyses) at the 5 and 95 percent confidence levels for the Proposed Action. The Orbiter and Lander-Only Mission Alternative, without the rover and its three RHUs, curium–244 and americium–241 sources, would be expected to yield correspondingly smaller collective (population) doses compared to the Proposed Action. The total probability of a Phase 1 accident resulting in a release of radioactive material and for the overall mission would be the same as for the Proposed Action. The expected Phase 1 collective (population) dose would be 0.0198 person-rem and for the overall mission would be 0.022 person-rem. The expected (mean) number of excess cancer fatalities would be about 9.93×10^{-6} or 0.00000993 for Phase 1 accidents, and about 1.10×10^{-5} or 0.0000110 for all mission accidents. The probability of one or more excess cancer fatalities for Phase 1 and the overall mission would be less than 1 in 500 million. The risk associated with a Phase 1 accident was estimated at about 3.11×10^{-8}, and about 1.18×10^{-7} for the overall mission.

The land area potentially affected by an accident was estimated for both the Proposed Action and the Orbiter and Lander-Only Mission Alternatives. It was estimated that less than 0.5 km^2 (0.19 mi^2) of dry land area would be contaminated above a representative screening level (USDOE 1999) across all mission accidents for the Proposed Action. For the Orbiter and Lander-Only Mission Alternative, the potential area of land contaminated would be a small fraction of that estimated for the Proposed Action.

Neither the Orbiter-Only Mission Alternative nor the No-Action Alternative would encompass any radiological risk associated with mission accidents. The Orbiter-Only Mission Alternative would have no radioactive material on board. The No-Action Alternative would cancel the mission.

Science Comparison

The Proposed Action would achieve all of the objectives established for the MS 01 mission and have a substantial positive impact on the broader strategy for Mars exploration. These contributions would be achieved through the carefully planned architecture for the mission with its orbiter, lander, and rover, and their associated science packages. Each of these major mission elements would individually return valuable scientific data and observations from orbit and on the surface of Mars, while functioning together to complement each other. Removal of the rover in the Orbiter and Lander-Only Mission Alternative would eliminate the capability for determining elemental composition of rocks and soil and would severely limit a Mars Surveyor Program goal of further characterizing the Martian surface at various sites on the planet. The Orbiter-Only Mission Alternative would eliminate all capabilities of the mission to perform in situ science and would have a significant adverse impact on a Mars Surveyor

Program goal of further characterizing the Martian surface at various sites on the planet. Under the No-Action Alternative none of the science planned for the MS 01 mission would be obtained.

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ABBREVIATIONS AND ACRONYMS

A

APEX	Athena Pre-Cursor Experiment
APXS	Alpha Proton X-ray Spectrometer
Al	aluminum
Al_2O_3	aluminum oxide
APCD	Air Pollution Control District

B

BEIR	Biological Effects of Ionizing Radiation (Committee on)
Bq	becquerel

C

^oC	degrees centigrade (Celsius)
CAA	Clean Air Act
CCAS	Cape Canaveral Air Station
CCDF	complementary cumulative distribution function
Cd	cadmium
CDF	cumulative distribution function
CDS	Command and Data Subsystem
CFR	Code of Federal Regulations
Ci	curie
Cl_2	chlorine
cm	centimeter
Cm	curium
cm^3	cubic centimeters
Co	cobalt
CO	carbon monoxide
CO_2	carbon dioxide
COMPLEX	Committee on Planetary and Lunar Exploration
CSD	Command Destruct System

D

dBA	decibels (A-weighted)
DEIS	Draft Environmental Impact Statement

E

EA	environmental assessment
ECFRPC	East Central Florida Regional Planning Council
EELV	evolved expendable launch vehicle
EIS	environmental impact statement
ERPG	Emergency Response Planning Guidelines
ESA	European Space Agency

F

^{o}F	degrees Fahrenheit
FDEP	Florida Department of Environmental Protection
FEIS	Final Environmental Impact Statement
FGFWFC	Florida Game and Fresh Water Fish Commission
FR	*Federal Register*
FSII	full stack intact impact
ft	feet
ft/s	feet per second
FTS	Flight Termination System
FUT	fixed umbilical tower
FWS	U.S. Fish and Wildlife Service

G

g	gram
Ge	germanium
GEM	graphite epoxy motor
GRS	Gamma Ray Spectrometer

H

H	hydrogen (H_2)
H_2O	water
ha	hectare
HAP	hazardous air pollutant
HCl	hydrochloric acid or hydrogen chloride
HEDS	Human Exploration and Development of Space
HEND	High Energy Neutron Detector
HTPB	hydroxyl terminated polybutadiene

I

IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IIP	instantaneous impact point
in	inch
INSRP	Interagency Nuclear Safety Review Panel
ISPP	in situ propellant production

J

JPL	Jet Propulsion Laboratory, California Institute of Technology

K

K	degrees kelvin
kg	kilogram(s)
km	kilometer(s)
km/hr	kilometers per hour
km/s	kilometers per second
km^2	square kilometer(s)
kN	kilo newton
kPa	kilopascals
KSC	Kennedy Space Center, NASA

L

lb	pound(s)
LC	launch complex
LCF	latent cancer fatality
LH	liquid hydrogen
LOX	liquid oxygen
LSB	launch service building

M

m^3	cubic meter(s)
m	meter(s)
m/s	meters per second
MARDI	Mars Descent Imager
MARIE	Martian Radiation Environment Experiment
mCi	millicurie
MDA	McDonnell Douglas Aerospace
MECA	Mars Environmental Compatibility Assessment
MEEC	Mars Experiment on Electrostatic Charging
MECO	main engine cutoff
MES	main engine start
MET	mission elapsed time
mg/l	milligrams per liter
mg/m^3	milligrams per cubic meter
mi	miles
MINWR	Merritt Island National Wildlife Refuge
MIP	Mars In situ Propellant Production Precursor (Experiment)
mm	millimeter
MMH	monomethyl hydrazine
MPa	10^6 pascals
mph	miles per hour
mrem	millirem
MS 01	Mars Surveyor 2001 mission
MS 03	Mars Surveyor 2003 mission
MSP	Mars Surveyor Program
MST	mobile service tower

N

N	newton
N_2H_4	hydrazine
N_2O_4	nitrogen tetroxide (NTO)
NAAQS	National Ambient Air Quality Standards
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NCRP	National Council on Radiation Protection
NEPA	National Environmental Policy Act
NESHAP	National Emissions Standards for Hazardous Air Pollutant(s)
NH_4ClO_4	ammonium perchlorate
nmi	nautical mile(s)
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
NOI	notice of intent
NS	Neutron Spectrometer

O

O_2	oxygen
O_3	ozone
OFW	Outstanding Florida Waters
OH^-	hydroxide ion
OSHA	Occupational Safety and Health Administration

P

P	probability
PAFB	Patrick Air Force Base, USAF
PAM-D	payload assist module-Delta (upper stage)
PAMS	Permanent Air Monitoring Station
PAN-CAM	Stereoscopic Panoramic Camera
Pb	lead
pCi/l	picocurie per liter
pH	measure of acidity
PLF	payload fairing
$PM_{2.5}$	particulate matter less than 2.5 microns in diameter
PM_{10}	particulate matter less than 10 microns in diameter
ppm	parts per million
Pt	platinum
Pu	plutonium
PuO_2	plutonium dioxide

R

REEDM	Rocket Effluent Exhaust Dispersion Model
rem	roentgen equivalent man

RF	radio frequency
Rh	rhodium
RHU	radioisotope heater unit
ROD	Record of Decision
RP-1	rocket propellant–1

S

s	Second (s)
S&A	safe and arm
SAEF	Spacecraft Assembly and Encapsulation Facility
SAR	Safety Analysis Report
SBCAPCD	Santa Barbara County Air Pollution Control District
SECO	second-stage engine cutoff
SER	Safety Evaluation Report
SHPO	State Historic Preservation Officer
SIP	State Implementation Plan
SLC	Space Launch Complex
SNAP	Systems for Nuclear Auxiliary Power
SO_2	sulfur dioxide
SPEGL	short-term public emergency guidance level
SR	State Route
SRM	solid rocket motor
SSB	Space Studies Board of the National Research Council
Sv	sievert
SVII	spacecraft intact impact

T

TES	Thermal Emissions Spectrometer
THEMIS	Thermal Emission Imaging System

U

μCi	microcuries
$\mu g/m^2$	micrograms per square meter
$\mu g/m^3$	micrograms per cubic meter
UDMH	unsymmetrical dimethylhydrazine
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
USAEC	U.S. Atomic Energy Commission
USAF	U.S. Air Force
USBC	U.S. Bureau of Census
U.S.C.	U.S. Code
U.S. DOE	U.S. Department of Energy
U.S. EPA	U.S. Environmental Protection Agency
U.S. FWS	U.S. Fish and Wildlife Service
U.S. NRC	U.S. Nuclear Regulatory Commission

V

VAFB	Vandenberg Air Force Base
VOC	volatile organic compounds

W

W	watt
WEB	warm electronics box
WMO	World Meteorological Organization

CONVERSION FACTORS

Linear

1 centimeter (cm) = 0.3937 inch	1 inch = 2.54 cm
1 centimeter = 0.0328 foot (ft)	1 foot = 30.48 cm
1 meter (m) = 3.2808 feet	1 ft = 0.3048 m
1 meter = 0.0006 mile (mi)	1 mi = 1609.3440 m
1 kilometer (km) = 0.6214 mile	1 mi = 1.6093 km
1 kilometer = 0.53996 nautical mile (nmi)	1 nmi = 1.8520 km
	1 mi = 0.87 nmi
	1 nmi = 1.15 mi

Area

1 square centimeter (cm^2) = 0.1550 square inch (in^2)	1 in^2 = 6.4516 cm^2
1 square meter (m^2) = 10.7639 square feet (ft^2)	1 ft^2 = 0.9290 m^2
1 square kilometer (km^2) = 0.3861 square mile (mi^2)	1 mi^2 = 2.5900 km^2
1 hectare (ha) = 2.4710 acres (ac)	1 ac = 0.4047 ha

Volume

1 cubic centimeter (cm^3) = 0.0610 cubic inch (in^3)	1 in^3 = 16.3871 cm^3
1 cubic meter (m^3) = 35.3147 cubic feet (ft^3)	1 ft^3 = 0.0283 m^3
1 liter (l) = 1.0567 quarts (qt)	1 qt = 0.9464 l
1 liter = 0.2642 gallon (gal)	1 gal = 3.7845 l
1 kiloliter (kl) = 264.2 gal	1 gal = 0.0038 kl

Weight

1 gram (g) = 0.0353 ounce (oz)	1 oz = 28.3495 g
1 kilogram (kg) = 2.2046 pounds (lb)	1 lb = 0.4536 kg
1 metric ton (mt) = 1.1023 tons	1 ton = 0.9072 metric ton

Energy

1 joule = 0.0009 British thermal unit (BTU)	1 BTU = 1055.1 joule
1 joule = 0.2392 gram-calorie (g-cal)	1 g-cal = 4.181 joule

Pressure

1 newton/square meter (N/m^2) = 0.0208 pound/square foot (psf)	1 psf = 48 N/m^2

Force

1 newton (N) = 0.2248 pound-force (lbf)	1 lbf = 4.4478 N

Radiation

1 becquerel (Bq) = 2.703×10^{-11} curies (Ci)	1 Ci = 3.70×10^{10} Bq
1 sievert (Sv) = 100 rem	1 rem = 0.01 Sv

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1. PURPOSE AND NEED FOR ACTION

This Draft Environmental Impact Statement (DEIS) has been prepared by the National Aeronautics and Space Administration (NASA) to assist in the decisionmaking process as required by the National Environmental Policy Act of 1969 (NEPA), as amended (42 U.S.C. 4321 *et seq.*); Executive Order (EO) 12114 "Environmental Effects Abroad of Major Federal Actions;" Council on Environmental Quality Regulations (40 CFR Parts 1500–1508); and NASA policies and procedures at 14 CFR Subpart 1216.3. This DEIS provides information associated with potential environmental impacts of continuing preparations for and implementing the Mars Surveyor 2001 (MS 01) mission. The MS 01 mission would conduct remote (global) and in situ (local) scientific investigations of Mars. The mission would consist of separately-launched orbiter and lander/rover spacecraft. The primary launch opportunity for the MS 01 orbiter is planned for March/April 2001 from Vandenberg Air Force Base (VAFB), California. The primary launch opportunity for the MS 01 lander/rover is planned for April 2001 from Cape Canaveral Air Station (CCAS), Florida. Chapter 2 of this DEIS evaluates the alternatives considered to achieve the MS 01 mission.

1.1 BACKGROUND

In 1978, following the successful Viking Orbiter and Lander missions to Mars, the Committee on Planetary and Lunar Exploration (COMPLEX) of the National Research Council's Space Science Board (now Space Studies Board) identified a list of prioritized, interconnected primary objectives for the continued exploration of Mars (Space Studies Board 1990). These are to:

- intensively study local areas of the planet;
- explore the structure and general circulation of the Martian atmosphere;
- explore the structure and dynamics of Mars' interior;
- establish the nature of the Martian magnetic field and the character of the upper atmosphere and its interaction with the solar wind; and
- establish the global chemical and physical characteristics of the Martian surface.

COMPLEX further stated that "… the global and in situ studies of the planet and the return of Martian material are complementary components of an overall program of investigation; each of the components is separately necessary," and that "… the return of unsterilized surface and subsurface samples to Earth is a major technique for the exploration of Mars."

In an update to its 1978 report, COMPLEX extended and revised these objectives for the exploration of Mars (Space Studies Board 1990), emphasizing that:

- the importance of the scientific objectives of study of the Martian atmosphere, interior, magnetic field, and global properties should be given equal priority with the objective of intense study of local areas; and

- the geochemical, isotopic, and paleontological study of Martian surface material for evidence of previous living material should be a prime objective of future in situ and sample return missions.

In 1994 NASA initiated the Mars Surveyor Program (MSP) to address many of the scientific objectives established by COMPLEX. The MSP consists of a long-term program that sends one or two small spacecraft to Mars during each launch opportunity beginning in 1996 and extending through the first decade of the new millennium. Favorable launch opportunities to Mars occur approximately every 26 months. The MSP encompasses all of NASA's Mars robotic mission activities and research undertaken to characterize the planet and its atmosphere, its geologic history, its climate and the relationship to Earth's climate change process; to determine what resources it provides for future exploration; and to search for evidence of past or present life on Mars. The MSP missions will also support data collection and technology demonstrations critical to planning and carrying out future human missions to Mars.

In the near term, MSP missions will either orbit Mars to perform global reconnaissance of the planet and its space environment, or land on the planet to perform in situ science. A long-term goal is to acquire and return the first carefully selected samples of Martian soil and rock by 2008. The earlier missions, in addition to other purposes, will facilitate this long-term goal by identifying those areas of Mars most likely to contain samples of scientific importance, including (potentially) evidence of past biological activity.

The initial two Mars Surveyor Program missions are the Mars Global Surveyor and the Mars Surveyor 1998 orbiter and lander.

- The Mars Global Surveyor was launched on November 7, 1996 and entered orbit about Mars on September 11, 1997. In March 1999 the spacecraft achieved its final mapping orbit to begin the global reconnaissance of Mars, gathering data on its surface features, atmosphere, and magnetic properties. This data will be used to investigate the surface processes, geology, distribution of material, internal properties, evolution of the magnetic field, and the weather and climate of Mars.

- The Mars Surveyor 1998 Orbiter (the Mars Climate Orbiter) was launched on December 11, 1998. The spacecraft was lost on September 23, 1999, as it was in the process of entering orbit about Mars. Its initial function was to provide primary command and data relay support to the Mars Polar Lander. Following that, it was to have begun its science mapping mission, which was to continue the global reconnaissance of Mars via imaging and systematic daily global sounding of the Martian atmosphere. NASA is in the process of determining how and when to recover this science as part of a future MSP mission.

- The Mars Surveyor 1998 lander (the Mars Polar Lander) was launched on January 3, 1999 and is expected to land in Mars' southern polar region on December 3, 1999. It will search for near-surface ice and possible surface records of cyclic climate change. During its 90-day primary mission, it will also characterize the physical processes key to the seasonal cycles of water, carbon dioxide, and dust on Mars. The Mars Polar Lander also acts as the carrier spacecraft for two micropenetrators. After separating from the lander before its entry into the Martian atmosphere, the micropenetrators will follow independent trajectories to impact sites in the southern polar-layered terrain. Capable of penetrating up to 2 meters (m) (6.6 feet (ft)) into the surface, each micropenetrator carries instruments to determine if water ice is present in the Martian subsurface and to measure the local temperature and atmospheric pressure.

Although not part of the Mars Surveyor Program, the Mars Pathfinder lander/rover was launched on December 4, 1996, and landed successfully in the Ares Vallis region of Mars on July 4, 1997. Mars Pathfinder was the second mission in NASA's Discovery Program, and was primarily an engineering demonstration of key technologies and concepts for eventual use in future missions to Mars. Engineering milestones of the mission included demonstrating a new way of delivering a spacecraft to the surface of Mars by way of direct entry into the Martian atmosphere, and delivering and operating a semi-autonomous roving vehicle (*Sojourner*) to the surface of another planet. Though designed to last only 30 days, Mars Pathfinder transmitted data for almost 90 days until contact was lost on September 27, 1997. It returned more than 16,000 images from the lander and 550 images from the rover, more than 15 chemical analyses of rocks, and extensive data on winds and other weather factors.

1.2 PURPOSE OF THE ACTION

The purpose of the action addressed in this DEIS is to further the scientific objectives of the Mars Surveyor Program by continuing the exploration and characterization of the planet. Specifically, the MS 01 mission proposed for launch would continue the global reconnaissance of Mars (via the MS 01 orbiter) and would intensively study an additional local area of the planet (via the MS 01 lander/rover). During its planned mapping phase of one Martian year the MS 01 orbiter would conduct a detailed mineralogical analysis of the planet's surface and measure the radiation environment. The orbiter would also act as a communications relay for the lander/rover. During its 90-day primary mission the MS 01 lander/rover would study soil and atmospheric chemistry and radiation at the surface.

1.3 NEED FOR THE ACTION

Among the other planets of our solar system, Mars most captures the human imagination. Mars has long had a special place in NASA's strategy for exploring the solar system. With its huge volcanoes and giant canyons, its polar caps and seasonal changes, and with the evidence of a warmer and wetter past, Mars is unique in its attraction as a target for scientific exploration. Mars is also of special interest because studying it may help unlock the secrets of Earth. Furthermore, Mars is the most probable target for eventual human exploration beyond the Moon.

At the highest level, the scientific objectives for Mars exploration are to determine whether or not life ever existed on Mars, and if so in what form; to better understand the climatic history of the planet; and to determine the mode of formation and evolution of the planet. These broad objectives then lead to more specific objectives, such as those put forward by COMPLEX and summarized in Section 1.1 above.

From a practical point of view, these objectives group naturally into those best achieved from orbit, on the planet's surface and/or with returned samples, and form the basis for individual mission objectives. The MSP has been structured in such a way as to systematically achieve as many of the scientific objectives as feasible within the practical constraints of available funding and technology readiness. Each mission in the long-term series contributes incrementally to the overall program objectives, gathering data which builds upon the knowledge and insights gained from prior missions. Thus, the Mars Global Surveyor and the MS 01 orbiter would continue the global reconnaissance of the planet with studies of the Martian atmosphere, interior, magnetic field, and chemical and physical characteristics of the surface. The landed spacecraft (Mars Polar Lander and the MS 01 lander/rover) would intensively study the diverse, local areas of the planet's surface and provide data that are essential for placing the global data in more meaningful contexts.

The 2001 mission of the MSP encompassed by the Proposed Action would continue the systematic exploration of Mars begun by NASA in 1996, building upon the scientific data already returned and expected to be returned.

1.4 NEPA PLANNING AND SCOPING ACTIVITIES

On April 3, 1998, NASA published a Notice of Intent (NOI) in the *Federal Register* (63 FR 16586) to prepare a Tier 1 Environmental Impact Statement and a Tier 2 EIS and conduct scoping for the Mars Surveyor Program. The scoping period ended May 18, 1998. One comment was received requesting a copy of the Tier 1 DEIS. No environmental issues were raised.

At that time, NASA's intent was that the Tier 1 EIS would serve as a programmatic EIS for the Mars Surveyor Program and as a mission-specific EIS for the Mars Surveyor 2001 and 2003 missions. Mission planning efforts called for the two missions to have identical lander/rover spacecraft that would, as part of their objectives, collect and store samples of Martian rock and soil for possible retrieval and return to Earth by a later mission. The later Mars sample return mission, now planned for 2005, would then be the subject of the Tier 2 EIS. The earlier missions in the MSP, the Mars Global Surveyor and the Mars Surveyor 1998, were the subjects of previous, separate NEPA documentation. While part of the long-term program, each mission was implemented with its own focused set of science objectives. The Mars Surveyor 2001, 2003 and 2005 missions were to be given programmatic treatment under NEPA because of their common objective of collecting and possibly returning samples of Mars.

Since publication of the NOI, NASA has, for a variety of technical and programmatic reasons, redirected the mission design architecture of the Mars Surveyor Program. The aspects of this redirection most relevant to this EIS were eliminating acquisition of samples for possible return as a MS 01 mission objective and deferring implementation of the advanced, common rover from the MS 01 mission to 2003. In its place on the MS 01 mission NASA substituted the engineering model of the Mars Pathfinder rover, upgraded to flight status, in order to preserve as much in situ science as feasible while reducing overall mission complexity and cost.

Because sample collection for possible return to Earth is no longer an objective of the MS 01 mission, NASA has determined that this mission can be given separate NEPA treatment. Accordingly, this DEIS addresses the potential environmental impacts associated with the MS 01 mission. Environmental impacts for normal and accidental conditions for the MS 01 mission are described. Later missions in the Mars Surveyor Program, including Mars sample return missions, will be covered by subsequent environmental documentation.

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